

Hands On Approach to Refinery Troubleshooting

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Troubleshooting is not an exact science. It begins with sound process and equipment knowledge, attention to detail, and good listening skills. From there, however, there is no blueprint or flowchart to success. Every problem is different, although specific techniques are applicable to several different types of problems. Experience can play a vital role, but only if used correctly. Do not assume that a specific problem exhibits the same set of symptoms every time, or that a problem with a similar set of symptoms has the same root cause.

The one universal truth of troubleshooting is that it cannot be done successfully from behind a desk. Even when the solution is arrived at by calculation the information required to perform the calculations is obtained through field work. Personal communication with operators, direct observation of field and control system data, even watching operators pull samples can provide a vital piece of information for solving a problem.

This paper illustrates the troubleshooting thought process and demonstrates a variety of troubleshooting tools using two refinery case studies. These problems are distillation related but manifested themselves differently and required different troubleshooting approaches. In both cases the refiners were losing a substantial amount of money because of the problem.

### **Troubleshooting Guidelines**

Troubleshooting begins with solid engineering fundamentals. Material and energy balances are as valuable as high tech gamma scans. It requires a sound understanding of the process and the specific unit in question. This includes the relevant theoretical background, process flow, instrumentation and control, equipment and piping details, as well as sampling and lab analysis details. Know where temperature and pressure indicators and sample points are located. This seemingly small detail can provide tremendous insight when analyzing the data they provide.

Effective troubleshooting requires understanding the symptoms that are being presented by the system. For example, flooding is not a symptom. High pressure drop, liquid carryover, poor fractionation, etc. are symptoms of flooding. They are also symptoms of other things. Always understand the symptoms that are being interpreted as flooding. They could point to something else. Sometimes there may not be a problem. Many operators and even engineers misinterpret an increase in pressure drop as the onset of flooding even though the tower is, in fact, lightly loaded and the pressure drop is just a natural reflection of an increase in internal reflux rates. This is only one example of problems that can be misdiagnosed because of a poor understanding of the symptoms.

One of the most effective ways to prepare for troubleshooting is to know how a unit operates when it is working well. This isn't just creating the charts highlighting operating parameters that are deemed critical at a high level. This means watching temperature profiles in distillation columns, preheat trains, and reactors. Know what the pressure drop is and what it should be. Talk to the operators about the unit. Go on rounds with them and watch what they do. Watch them pull samples. Know what the samples look like. This way, when something changes you know what it is and have a head start on solving the problem.

There is no substitute for spending time in the field learning a process unit. Know where the key pieces of equipment are located. Follow the piping for major streams. Sometimes things that do not seem out of the ordinary on paper will stand out in the field.

Use a "system oriented" approach to troubleshooting rather than a unit operation focus. This approach begins with the problem symptoms (e.g. high pressure drop in a column) and evaluates potential causes to determine the root cause. If the focus is too narrow there is a risk of a "fix" that masks the symptom and ignores the problem. This doesn't mean that every gas plant problem can be traced back to a change in crude slate. It does mean that good

troubleshooters understand the potential for other refinery processes to cause or contribute to problems in any given unit.

Practice good listening skills. Not only does this allow for efficient information collection but it helps you establish credibility. Never immediately challenge a diagnosis provided by another individual. Understand the observations they made that led to their diagnosis. They might be right and even if they are wrong, their observations may prove valuable.

Never underestimate the importance of the information you can get from operators. They are generally very good at describing the symptoms. Often their knowledge goes unused because their analysis of the symptom is inaccurate and therefore discarded. Learn how to ask the right questions to get to the description of the symptoms.

Occasionally troubleshooting just happens. The right piece of information clicks and the root cause is apparent. Most of the time it is not that simple. There is either no readily apparent cause or many to choose. When this happens it becomes necessary to troubleshoot by the process of elimination. Develop a hypothesis based on the available data of the potential causes. Then design an experiment to eliminate or confirm that hypothesis. Conduct the experiment and evaluate the results. If the experiment rejects the hypothesis eliminate it and move on.

Don't get hung up on a preferred theory. If the data show a hypothesis is not correct come up with a new one. Sometimes this will be difficult because of emotional ties to the idea. However, chasing a theory after the data reject it is a waste of valuable time.

## **Troubleshooting Case Histories**

### Increased FCC Fuel Gas Production

The Fluid Catalytic Cracking Unit (FCCU) in a North American refinery experienced a gradual increase in the production of fuel gas, a low value byproduct of the catalytic reaction that converts high molecular weight gas oils into motor fuels. The unit processes a mixture of virgin and coker gas oils, all of which is hydrotreated to remove sulfur and other impurities and saturate aromatics.

The initial investigation into the problem determined that the nickel and vanadium concentration on the FCCU catalyst had increased in correspondence with the increased production of fuel gas. These metals act as a dehydrogenation catalyst in the FCCU reactor, resulting in an increase in fuel gas production. The increase in metals on the catalyst could be due to:

1. Reduced FCCU catalyst addition rate.
2. Reduced metals removal in the upstream hydrotreater.
3. Increased metals concentration in the feed to the hydrotreater.

The FCCU catalyst addition rate is a key operating parameter and is monitored on a frequent basis. The catalyst addition logs were reviewed and compared with catalyst receipts. This comparison did not indicate a reduced addition rate. Furthermore, other catalyst parameters such as surface area indicated that catalyst addition rate had been constant over the time period in question. Reduced catalyst addition was ruled out as a cause.

The FCCU feed was periodically monitored for both nickel and vanadium. Neither of these contaminants had increased above the 0.5 ppm detection limit of the test method over the time period that the concentration built on the FCCU catalyst. A metals balance on the FCCU quickly demonstrated, however, that the amount of nickel and vanadium required to reach the existing concentration on the FCCU catalyst were below the detection limit of the test method. It was not possible to completely rule out a reduction in hydrotreater demetallization performance as

the root cause for the increase in FCCU catalyst metals concentration. However, no other hydrotreater performance measure (sulfur and nitrogen removal, con carbon reduction, and hydrogen addition) showed signs of significant degradation. Hydrotreater performance was ruled out for the time being as the root cause.

The crude unit HVGO product was periodically monitored for both nickel and vanadium. This monitoring showed an increase in both nickel and vanadium but they were not consistently high over the time period. Also, the concentrations were not consistently high enough to expect the type of increase exhibited by the FCCU catalyst. However, the samples were only pulled for metals analysis a few times per month. No metals concentration data were available for the majority of the operation. Further investigation was necessary.

Vacuum gas oil metals concentration is affected by volatile organometallic compounds and entrainment of resid into the gas oil. Volatile metals are a function of crude slate or contaminants. Crude assays showed no expected increase in volatile metals over the time period in question. Entrainment is a function of column C-factor. It is possible to estimate the C-factor using measured vacuum tower product rates and flash zone conditions. The C-factor was correlated versus gas oil metals concentration for the days when data were available. The result is shown in Figure 1. Above a C-factor of approximately 0.32 the metals concentration increases exponentially. A review of operating data showed an increase in average vacuum tower C-factor correlated very closely with the increase in FCCU catalyst metals.

Other factors beside C-factor that affect entrainment in a vacuum tower include wash zone design, feed device type and design, and transfer line design. All three were found to be deficient in this vacuum tower. However, the next unit turnaround was only months away so attention focused on improvements the wash zone as having the highest probability of success on a short timeline.

The existing wash zone consisted of five feet of FLEXIGRID<sup>®</sup>. FLEXIGRID<sup>®</sup> is effective at de-entrainment for C-factors up to approximately 0.3. Above that structured packing is recommended. The wash zone was re-designed using a combination bed of FLEXIPAC<sup>®</sup> structured packing and FLEXIGRID<sup>®</sup>. In addition to providing better de-entrainment this design is more efficient resulting in greater wash oil vaporization. This required replacing the wash oil spray header to provide sufficient wash oil to prevent coking the bed.

The wash zone revamp was completed along with other unit modifications that allowed the unit to increase charge rate. Wash bed performance was greatly enhanced, resulting in reduced metals in the HVGO at C-factors approaching 0.5 as shown in Figure 1.

### Premature DIB Flooding

The deisobutanizer (DIB) in a sulfuric acid alkylation unit separates excess isobutane from normal butane and alkylate product for recycle to the alkylation reactors. Isobutane purity is a key variable since impurities take up space in the alkylation reactors and increases the heat load on the refrigeration system. One unit was unable to achieve the desired overhead purity due to flooding of the DIB. However, an evaluation of the DIB trays based on a simulation of the column indicated they were operating at approximately 70% of flood. Capacity should not be an issue.

A closer comparison of the simulation with the process data showed a significant difference between the calculated and actual DIB reboiler duties. The process data showed a higher heat requirement than the simulation. Further evaluation was required.

This DIB column is equipped with a vapor side draw that feeds a butane rectification column as shown in Figure 2. Liquid from the bottom of the butane rectifier returns to the DIB by gravity

flow through a seal loop. Discussions with the plant operators revealed that they frequently had to drain water from the bottom of this seal loop to maintain this flow. Water was not accounted for in the original simulation. Because the entire process of draining the water was executed manually there was no way for the engineer to know it was an issue without communicating directly with the operators.

The DIB and butane rectifier were re-simulated with water in the feed. It quickly became clear that no significant water could accumulate in the butane column assuming that it was removed from the DIB overhead accumulator as it was produced. However, the existing overhead accumulator was not designed for proper water removal. The accumulator hydrocarbon draw off nozzle was equipped with a 2" internal projection. The accumulator also had a water "boot" consisting of a 4" diameter x 3' long pipe on the bottom of the vessel. The operators drained this on their rounds every two hours. Rough estimates of the expected water feed rate to the tower indicated that this arrangement was not sufficient.

During a routine round, the length of time required to drain the water from the overhead accumulator water boot was measured. After a 15 minute wait, the experiment was repeated with no significant change in the draining time. Clearly, the existing water boot was being filled in less than 15 minutes. Once the boot was full, any additional water left the overhead accumulator with the hydrocarbon draw and was either refluxed to the DIB or recycled to the alkylation reactors. Water refluxed to the DIB resulted in excess load on the trays and the reboilers. Water recycled to the reactors could contribute to excess acid consumption if not removed.

The DIB overhead accumulator was re-designed with a larger water removal boot and a coalescer to improve water removal efficiency. The projection at the hydrocarbon draw off nozzle was extended to 6". In addition, the boot was equipped with a level controller to draw off the water continuously.

The modifications were implemented and DIB performance was notably improved. Normal butane concentration in the isobutane product dropped by nearly 2% and the tower no longer floods. Tray efficiency also improved substantially.

## **Conclusion**

These case studies illustrate a few of the key elements of troubleshooting. Engineering fundamentals are the foundation for successful troubleshooting. Follow a systematic approach. Understand how the unit operates and how it should perform. Communicate with the operators. Go out in the unit and find out first hand what makes it tick. These things won't make you a troubleshooting expert. However, these fundamentals form the foundation for a successful troubleshooting experience.

Figure 1: HVGO Metals (Ni + V) vs. Wash Zone C-factor

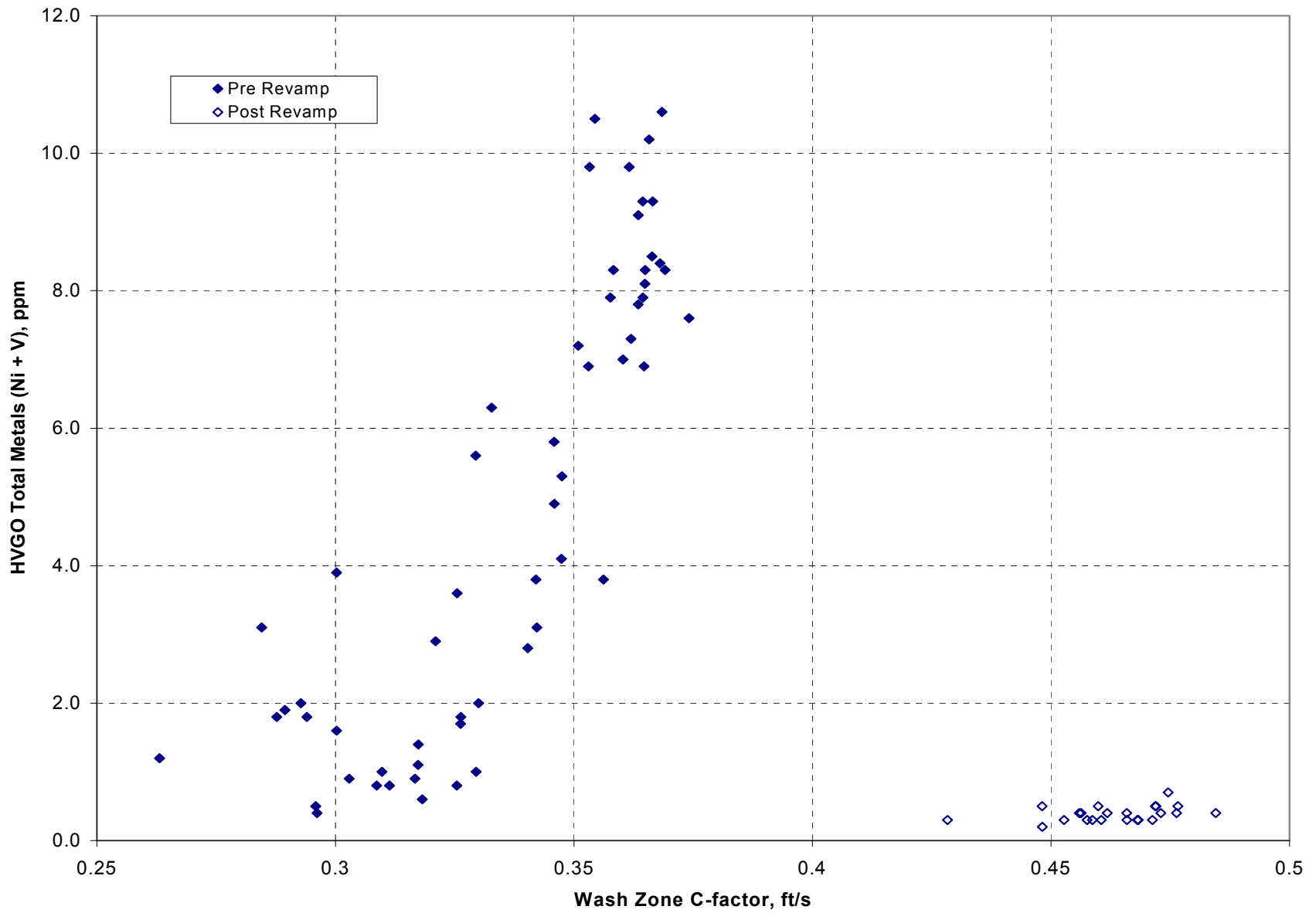


Figure 2: Alkylation Unit DIB Process Flow

